THE CURCULIONIDAE OF ALFALFA IN KANSAS

by

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INTRODUCTION

The insects attacking alfalfa in Kansas are of prime importance to two groups of farmers in this state, the livestock man who depends upon alfalfa for feed, and the forage crops man who grows alfalfa as a cash crop.

For this reason Kansas Experiment Station Project 115 entitled, "Insects Injurious to Alfalfa and Allied Plants", was established in 1916 at this Station for the purpose of studying the life histories and control measures necessary to combat these injurious insects.

While engaged as a research assistant in the field and laboratory work on this project the writer became in-

terested in the species of the family Curculionidae*. This interest was excited by the fact that at least three species of this family were very abundant in the alfalfa fields and each was doing serious injury to this crop. In addition the knowledge of two of these, Sitona hispidulus (Fab.) and Epicaerus imbricatus Say. was scant. Considerable information concerning Hypera punctata (Fab.) could be gathered from the work of other stations, but no studies had been made under Kansas conditions.

The subject was limited to a life history study in an attempt to gain as complete a knowledge concerning the life history, the habits, and injury done by this group as possible in the hope that this knowledge would simplify and hasten the perfection of control measures.

The results of over 15 months of intensive research on the three most injurious species, Sitona hispidulus (Fab.), Hypera punctata (Fab.) and Epicaerus imbricatus Say. is recorded below.

Phytonomus posticus (Gyll.), not yet found in Kansas, and at present limited to Utah, Colorado, Oregon, Idaho, and Wyoming, may reach this state any time in which case it will undoubtedly become a serious problem. The region

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*Family Curculionidae, suborder Rhynchophora, order Coleoptera.

in which this insect is now found is crossed by the Union Pacific and Denver and Rio Grande railroads. Both of these come directly to Kansas thus furnishing excellent opportunity for the weevils to spread to alfalfa here.

Highways are also a source of concern to Kansas farmers as a mode of weevil distribution. Freight cars from the infested district have been inspected in Kansas and surprisingly large numbers of live weevils taken from them. Trunks and grips brought from Utah to Kansas have been found to contain a dozen or more weevils after reaching this state. With these facts in mind it is well to be on guard against this destructive pest. However, because this insect is not yet an alfalfa pest in Kansas further mention of it will not be made except in the key to the larvae of the Curculionidae attacking alfalfa in Kansas.

REVIEW OF LITERATURE

General

In the preparation of this paper a thorough review of the literature on 23 species has been attempted, a procedure which necessitated the reading of 187 references, 53 of which contained material valuable enough to abstract. With the 32 references cited in the bibliography following, the 300 given by Titus (28) and with those given by Jackson

(17) (16) almost a complete set of references may be had on the subject.

Three papers (28), (16), (17) were found to be almost indispensable in the study of three species of alfalfa insects.

A paper by Titus (28) is principally taxonomic in nature and deals with the two genera Hypera and Phytonomus. To these genera belong two species, Hypera punctata (Fab.), and Phytonomus posticus (Gyll.), of interest to Kansas alfalfa growers, and two other species which are potential pests and found in Kansas. For all of these Titus gives the life history, distribution, habits, food plants, and control measures. Further reference to this paper will be given in later discussions.

Two papers (16), (17) by Dorothy J. Jackson, an English worker, on the genus Sitona, aided considerably in the study of S. hispidulus (Fab.). In the first paper (16) there is a complete discussion of Sitona lineatus L. a species not occurring in Kansas but one whose life history and stages are almost identical with those of S. hispidulus (Fab.). In addition a key to all the species of the genus Sitona in Britain is given, including drawings of scales, setae, dorsal and lateral view of adults, and the external and internal sex differences.

The second paper (17) is an admirable presentation of Sitona hispidulus (Fab.) giving life history, host plants, external and internal morphology of each of the stages, and rearing methods used in making the study. In general the life history of this species in England and Kansas are quite similar except in the number of generations per year. In Britain there are two broods a year, one in the fall, and another in the spring. From the observations made by the writer, in Kansas only the spring brood occurs.

Other referances deal with individual species and are discussed under their respective headings.

METHODS

In order to obtain a list of the species of Curculionidae found inhabiting alfalfa in Kansas several methods were used:

1. Sweepings taken on alfalfa during each season of the year.

2. Collections at lights in the alfalfa field.

3. Examination of debris taken in the field.

4. Holes dug in the alfalfa field at different seasons of the year to collect ground forms.

The alfalfa insect collection built up since project 115 was started was identified by W. P. Hayes and L. L.

Buchanan and has been used as a guide to the species to be studied in this problem.

The methods used in attempting a comprehensive study of the Curculionidae of alfalfa of necessity falls into two distinct classes; those used in the study of subterranean insects and those used in the study of above ground forms. The former presents by far the greater difficulties and on account of the complexity of a biological study of this kind more than one year is needed to complete the work in a satisfactory manner. In the study of terrestial insects observations are more easily made, insects more easily kept alive, and measurements of growth more easily taken, than is the case with subterranean forms.

The insects which are for the most part terrestial may be divided into two classes, those which feed internally on the host plant and those which feed externally. Of the external feeders only one species, H. punctatus (Fab.), has been found inhabiting the alfalfa plant in which the larval as well as the adult stage is spent on the plant. In this case salve box rearings were made using one-ounce plain tin salve boxes. Over wintering cages of fine mesh screen wire were used. Cages a yard square were found most suitable. Detailed field observations were made at short intervals over different parts of the state, especially in Riley,

Wyandotte, and Wabaunsee counties. Rearing cages in the field were also used to aid in checking field observations. These cages were 18 inches in diameter and two feet high. They were staked down to the ground and were opened by a lid which formed the top of the cage.

The purpose of the salve box rearings was to furnish material close at hand for taking head capsule measurements as a method of determining the number of instars as well as the size during each instar, to study parasites and diseases, to observe spinning of cocoons, copulation, oviposition, changes in color, activity of the larvae, and many other minor details for which very close observations were necessary.

To the other group of insects, those which feed internally on plants belong a fairly large number of species collected on alfalfa. None of these are alfalfa pests but most of them feed as larvae in the roots, stems, or seeds of the plants growing in or around the alfalfa field.

The group of insects which spend much of their time below the surface of the soil contains at least one very injurious species, Sitona hispidulus (Fab.). To this group also belongs Epicaerus imbricatus Say. The methods used in the life history studies of this insect were several in number. Oviposition was obtained in lamp chimney cages

and salve boxes. In 1928 larvae were reared in salve boxes. The method used was to fill the salve boxes with sifted soil; then a small alfalfa plant was laid on top of the soil and a few feeding roots covered with packed earth. This served to keep the alfalfa plant alive and forced the larvae to feed on the surface if any food was obtained. Thus, the growth and head capsule measurements could be taken, although in a rather inconsistent manner. Rearings were also attempted in salve boxes containing moist blotter which prevented desiccation of the larvae. Alfalfa roots cut into small bits were added. As one might expect who is acquainted with the difficulties of rearing subterranean insects the mortality with both of these practices was high. For that reason rearings during the fall of 1928 and 1929 were made by other methods.

In the fall of 1928 adult clover sitones were brought in from the field and kept under room temperatures. This constant higher temperature stimulated egg laying. When the eggs hatched the young larvae were reared on three year old alfalfa roots. The roots were cut up into sections about two inches long. A small cavity approximately two millimeters square was made in one side of these large roots and into each a single larva was put. The cavity was then covered by a large piece of root epidermis and

securely held in place by pins or a string. This section of root was then buried in moist soil or simply put in the tin container with moist blotting paper. As the larva grew the cavity was enlarged by feeding. Head capsule measurements were thus obtained more easily. The mortality was not so high as in the former two methods. It might be stated here that it is almost impossible to handle these larvae, even enough to get instar measurements and yet have them survive. Neither the larvae nor the pupae can be handled or shaken without danger of injury.

Probably the most successful rearing methods were the ones perfected during the spring and summer of 1929. Young white clover and alfalfa plants were placed in finely sifted soil between clear glass plates. These glass plates were not more than two millimeters apart. Around the edges was put a small band of blotting paper to hold the soil in place as well as to aid in the absorption of moisture. The glass plates were held together by rubber bands or some adhesive material. Since only two millimeters of space was allowed between the glass plates most of the movements of the larvae could be observed. In this way handling the larvae was eliminated.

Two sizes of such glass cages were used; one 3 by 1.5 inches as an individual cage, and another 3.25 by 4 inches

for several larvae. By this method all movements, all developmental stages, and the effect on the host plant could be closely watched.

By noting oviposition and the time of hatching and supplementing these observations with field observations of the larval and pupal stages the writer was able to follow closely the seasonal history of this insect. The pupal stage is the most difficult stage to observe and in order to rear the insects through this period it seems necessary to let the larvae construct their own pupal cells. In order to be able to observe the insects after the pupal cell was made the mature larvae were put in glass cages (Plate II) to pupate.

The number of instars of the larval period was determined by head capsule measurements taken with a Leitz Wetzlar binocular microscope. A 7.5 ocular micrometer was a part of this equipment and in most cases a 32 or a 48 millimeter objective was used.

The most recent type of rearing cage and one which at present indicates success is one developed by Bryson*.

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Six inch unglazed tile one foot in length is used. In some cases one tile is set in the ground 22 inches deep and another placed on top. In others the cages are only one tile deep. A round screen cage approximately 20 inches high having a cone shaped top is constructed to fit tightly around the outside of the tile. A screen over the top of the tile is not absolutely necessary in rearing curculio larvae which feed below the surface, but it prevents other insects from feeding on the plants and so enhances the possibilities of obtaining vigorous plants. After these tiles were filled with soil, alfalfa seeds were planted or young plants set in them. As the curculio eggs hatched the larvae were placed on the surface of the soil within the cage and allowed to enter the soil as is the characteristic manner of the species. In this type of cage only one vigorous alfalfa plant is grown. Fifty or one hundred larvae are put in each cage. Rearings of this kind have not been practiced over a long enough period to indicate definitely to what extent success will be obtained with Curculionids, but the excellent results experienced in wireworm rearings by Bryson last year encourages the use of this type of cage.

Practically the same methods were used in the rearing of Epicaerus imbricatus Say. as for S. hispidulus (Fab.). To supplement insectary methods many larvae were collected

by digging in pasture or prairie land. Larvae collected in this manner were often nearly full grown.

TYPES OF FEEDING AND LEAF INJURY

The average farmer generally notes the injury to the leaves of his alfalfa crop before that of other plant parts. For that reason Plate I has been prepared showing the three characteristic types of injury made by the adults of the three curculios. Since the injury is so outstanding and characteristic for each species little trouble will be encountered by the layman in placing the blame for the injury where it belongs.

The size of the plants in Plate I is reduced nearly one-half and the picture was taken of plants fresh from the field. Plant 1 shows injury by Sitona hispidulus (Fab.). The lower branch shows best the type of injury caused by the adult Sitona. The lower leaves are eaten first although the top ones have also been attacked. In looking for injury caused by this insect one generally finds the leaf margins eaten leaving the kind of cresent-shaped, notched appearance shown here. Seldom are the leaves entirely stripped from the stem as shown by plant 2.

Plant 2 shows the injury by *Hypera punctata* (Fab.). With this insect defoliation is often complete especially on new growth following a cutting of alfalfa. The entire leaf is eaten leaving only the midrib, and often that is consumed. The lower leaves are always eaten first leaving the terminal bud to be the last part destroyed. For this reason this type of injury often looks serious but since the early lower leaves usually drop off before the crop of hay is cut anyway, the plants generally recover.

Plant 3 shows injury by the imbricated snout beetle, *Epicaerus imbricatus* Say. This type of injury is general over the entire plant. The insects do not attempt to hide or feed under cover. They often eat the leaf petiole thus letting the leaf fall to the ground. The margins of the leaves are left ragged and frayed. This insect does not cut off leaf tissue sharply with the mandibles but rather grasps it and tears it loose. For this reason fresh injury often shows bruised leaf margins with the midribs and leaf veins sticking out unevenly and ragged along the margin of the injured leaf. In feeding this insect often destroys the entire growing terminal bud, even more completely than is shown half way up on the right in Plant 3. The imbricated snout beetle is by far the most ravenous feeder of the Curculionids.

The clover leaf weevil feeds very extensively also. Both of these insects cause defoliation much more quickly than the clover sitones. In order to connect the type of larval injury with the right curculio larva the following key has been prepared in which the place of injury, type of injury, and difference between the species of the larvae are differentiated.

A KEY TO THE LARVAE OF CURCULIONIDAE ATTACKING ALFALFA

A. Larvae which feed on stems or leaves of alfalfa during spring and summer; in winter lie hidden beneath rubbish and debris.

1. Larvae usually light green curling up tightly with tip of abdomen overlapping head when disturbed. But few black spots on each segment. When very young (early spring and late fall) feed in growing alfalfa buds. When older feed on expanded lower leaves. Lower leaves eaten first. Either part or entire leaf consumed.

<u>Hypera punctata</u> (Fab.)

2. Young larvae pale dirty yellow, later green, do not curl up tightly but lie in half circle, tip of abdomen not overlapping head. Row of black spots laterally on each segment.

When very small larvae feed on developing buds, when older feed on leaves in open. Lower or upper leaves consumed, midribs and leaf veins usually left. Often skeletonizing leaves.

<u>Phytonomus</u> <u>posticus</u> (Gyll.)

B. Larvae which feed on roots of alfalfa.

1. Larvae very small, wrinkled and lying in a curved position. No prothoracic shield or ocelli. Grooves eaten in large tap roots. Nodules hollowed out by small larvae.

<u>Sitona</u> <u>hispidulus</u> (Fab.)

2. Larvae very small to 3/4 inches in length, ocelli present. Prothoracic shield conspicuous and shining. Fiberous roots followed and entirely consumed as larvae burrow alongside.

<u>Epicaerus</u> <u>imbricatus</u> Say.

<u>SITONA</u> <u>HISPIDULUS</u> (FAB.)

Introduction

Up to the present most workers have considered <u>Hypera</u> <u>punctata</u> (Fab.) to be the most serious curculio working in alfalfa. After two years observations of alfalfa curculios

the writer considers the clover sitones to be the most serious for the following reasons:

1. The feeding of the larvae on the roots during the spring provides an excellent source of infection for alfalfa root and stem diseases at a time of the year when the soil is moist and diseases spread rapidly.

2. Not only do the larvae do serious injury to the roots of the alfalfa plants but the adults feed throughout the summer on the green leaves and may even become so numerous that they destroy entire fields of alfalfa.

Correspondence in the files shows that in Illinois this insect was first noted in 1920 when alfalfa fields were practically destroyed by the clover sitones, 25 or more beetles being found around a single plant. Beetles driven out of a clover field by plowing went across the road to an alfalfa field and destroyed the alfalfa for a rod or two along the border.

3. Fungous and bacterial diseases and predatory insects and birds seem to be fewer in number and less effective in checking this pest than is the case with Hypera punctata (Fab.).

4. In all stages this insect is so small that except in a few cases they go on unnoticed and unchecked.

5. The larvae cut off the fine feeding roots and often completely girdle the large tap roots an inch or two below the surface.

6. The damage done to alfalfa fields while great is not conspicuous at any one time, but in most cases, is constant, and extends over a large territory. During the spring there is a period in which the larvae may be found feeding on the roots in great numbers and at the same time the adults may be feeding quite extensively on the leaves.

Sitona hispidulus (Fab.) was first noticed by Le Conte at Long Beach, New Jersey, in 1876, on grass roots. The distribution, according to Blatchly and Leng (1) and Webster (30) is from Ottawa, Canada and New England to Nebraska and south as far as the District of Columbia. The territory also includes Washington, Oregon, Colorado, Kansas, Missouri, Kentucky and Tennessee.

Howard (12) gives the host plants as blue grass, alfalfa, red and white clover, and Jackson (16) adds to this list peas, beans, vetch and lupines.

Damage

The injury done by the clover sitones has very often been confused with that of S. flavescens Marsh. and other species of Sitona as well as that of Hylastinus obscurus (Marsh.) (16). In 1919 much damage was done by Sitona

hispidulus in Ohio (21). Parrott (23) recorded great damage done to young alfalfa plantings in Seneca and Ontario Counties, New York, and states that although clover seems to be the favorite host yet it was feared that it will become an important alfalfa pest. The first proof of damage done to alfalfa as given by Webster (30) was on a farm in Maryland in June, 1910. The field contained spots which looked poor and unhealthy. Examinations showed both tap roots and laterals badly damaged. On these were found grooves and oval patches which had been eaten. The injury on the roots extended down to five inches. Twelve to twenty larvae were found in each shovel full of dirt. The same year the condition was very much the same over the whole country. During July of the same year much complaint was recorded for Pennsylvania.

Life History

The life history as given by the various workers is as follows:

Worker	Days Egg stage	Days Larval stage	Days Pupal	Days Adult	Days egg to adult
Howard	13	11-21	8-10	--	38-43
Blatchley and Leng	--	17-21	--	--	38-43
Jackson	25 days to 7 months	8-16 weeks	28	--	--

Egg. The freshly laid egg is white but not shining and is oval in shape. It is four millimeters long and .3 to .35 mm. wide. The variation in size is so slight that it is difficult to detect. Soon after being laid (24 hours) the eggs turn to a shining jet black. The shell becomes more rigid and brittle with age.

Webster (30) states that egg laying in the field has never been observed for this insect. According to Blatchley and Leng (1) the eggs are laid on the under side of the leaves. Hudson (15) had one female which laid 163 eggs. He found the length of the egg laying period to be 30 days. He made observations of the oviposition of caged females. Of 1363 eggs laid 67 per cent were laid on glass chimneys, 17 per cent on leaves, 13 per cent on soil, and the remainder on stems and petioles. At this Station females have been observed to oviposit under field conditions during April, May, June, July, September, October and November, and at room temperatures during December. There seems to be no question but that oviposition takes place whenever the weather is not too cool in the fall or too hot in the summer. One caged female laid 37 eggs in two days, the highest previous recorded being 12 in one day.

The length of the egg stage under mild weather conditions is very short averaging from six to nine days with

the majority of eggs hatching in eight days after oviposition. Although none of the observations made at the Kansas Station prove definitely that eggs overwinter without hatching, none disagree. Owing to the fact that the eggs are so small and hard to find this is a difficult matter to determine under field conditions. Since the adults lay eggs readily in fall either in the insectary or in the open on warm days and since no larvae have ever been found in the fall in the field it appears that eggs laid in the fall either perish during cold weather or hatch in the spring. Oviposition in the spring in the field does not begin till late April or May according to the observations of this Station. In England the eggs often overwinter before hatching and this may prove to be the case in Kansas. The period of greatest oviposition is from May 15 to June 15, although it may occur in late April if the weather conditions are favorable.

The larvae emerge from the egg by cracking the shell at one end. After the larva leaves the egg the old shell retains its normal shape but shows a round jagged opening in the end.

Larva. The newly hatched larva is a transluscent greyish white, with a very light brown to straw colored chitinous head. There are no ocelli present. A few

bristle-like hairs project from the head capsule. The body is much wrinkled, footless, and has a pair of anal prolegs. Several very long slender hairs occur over the body being more numerous near the posterior extremity. The head measures approximately .162 mm. wide, and the body .945 mm. long. As the larva becomes older and some food has been taken into the crop, which is enormous in size as compared to the size of the larva, the color changes. In the middle of the dorsum the contents of the crop shows dark or brownish. The lighter parts of the body become somewhat milky and change to a creamy white about the time for pupation. Just before pupation the brown color from the crop contents disappears.

According to Blatchley and Leng (1) and Webster (30) there are two generations per year in the warmer climates of the area in which the clover sitones are found. This condition is not true for Kansas during the two years this insect has been studied. Upon hatching the larva begins to crawl very rapidly. If the egg is on the leaf the larva crawls till it falls to the ground. It wiggles along the surface till a protection from the sun can be found. Finally a crack is found and the larva enters the ground. Hours have been spent watching newly hatched grubs enter the soil and in no case have they been seen digging in. In several cases when larvae entered the soil they began

feeding on clover nodules or roots in less than twenty minutes. It is very evident that feeding is begun as soon as contacts with tender roots are made. The details of feeding were noted through glass rearing cages.

The clover sitones passes through five instars, the measurements of one of which are given below:

	1st instar	2nd instar	3rd instar	4th instar	5th instar	prepupa
Head capsule measurement	.162 mm.	.27 mm.	.55 mm.	.67 mm.	.8 mm.	11-21-28
Number of days	11	9	7	8	13	

In the fall of 1928 eggs kept under room temperature hatched 10-15-28 and became mature larvae 11-20-28. At that rate only about 45 days are necessary for the larva to become adult from the time of hatching.

The foregoing instar measurements were kept during October and November of 1928, and developed somewhat more slowly than those which were not handled, taking 48 days to develop from the egg to the pupa.

Different individuals, after the second molt, vary so much in width of head capsule during the same instar that it is impossible to give the extremes of each instar without an overlapping. For this reason the foregoing table shows

only one larva followed through all the molts. Even though every care possible was exerted to get accurate measurements there are possibilities of slight error in this table on account of the difficulties encountered in taking the measurements.

The first molt of a larva was observed under a binocular microscope from beginning to end. The head capsule came off first. After wriggling around eight minutes trying to crawl from the exuvae the larva seemed to tire. It quit wriggling. The writer, thinking the molt skin might have dried to the larva, touched it with a little water. The skin came off immediately. The only part of the larva showing color was the tips of the mandibles. These were a reddish brown.

Since a large percentage of the eggs hatch in the field from May 5 to 15 damage to the alfalfa crop occurs from May 18 to about July 1. Between these dates most of the larvae are at least in the third instar or older and although considerable feeding is done before this stage most of it is done on smaller roots.

Subterranean activity. Although the larvae burrow through the soil to a considerable extent after the second instar, up to that time they seem to be too weak to burrow extensively. They seek cracks or open spaces by which they

migrate through the soil rather than by digging. In many cases an opening may be made larger by forcing the body through it without actually digging the earth out of the way.

A good deal of damage to the roots is done by these larvae. When a small feeding root is encountered it is eaten off and another is then sought. At this stage the larvae seem to find roots by chance only. They crawl through cracks and other soil openings and feed on whatever they come in contact with. Often the larger fiberous roots are eaten in two. It is plain enough that if the numbers of larvae are large the cutting off of these feeding roots will be of some consequence to the parent plant. Seldom does the young larva follow a root after severing it from the plant. The ideal spot for feeding seems to be in the nodules. The writer has seen large nodules attacked within which the larva fed for three or four days. In such cases a hole is made in the nodule slightly larger than the diameter of the larva. Then the larva crawls inside and feeds on the contents finally leaving nothing but the outer shell of the nodule.

As the larvae pass the second instar they become more active. Up to this time they may be found almost any place in the soil and they seem to depend upon the roots being thick enough in the soil to furnish them a good supply of food. After the second molt the migration seems to be more

definite. The movement is toward the larger roots, and may be to a greater depth. This concentration toward one small area with the great increase in numbers found there often causes serious damage to the alfalfa.

Actual burrowing now takes place, and in doing so the soil is dug loose with the mandibles either closed or open. The head is extended against the front of the tunnel and then brought forward and downward. In this manner the soil which has been loosened is carried down beneath the abdomen. The body of the larva just posterior to the head is then much enlarged, more noticeably on the ventral side, and by muscular contractions this enlargement passes back almost to the tip of the abdomen in a wave-like fashion. By this movement the loosened earth is rolled backward. After this the tip of the abdomen is contracted until the loosened earth is behind it, then the abdomen is extended. This presses the earth backward in the tunnel and pushes the larva forward.

By turning from side to side the larva is able to burrow in a straight line, although the normal position of the larva is a somewhat curved one. Several small balls of earth are dug loose and packed tightly behind the larva in the burrow. The larva then turns a half or a quarter of the way over in the tunnel and repeats the process. In

this manner a burrow is sometimes made for four or five inches in a straight line.

During the last half of May and the first half of June enormous numbers of fourth and fifth instar larvae may be found feeding on the roots. The writer made many counts of the larvae at the time they were most abundant in the field. The results of two such counts are shown below, each of which was made on a different basis.

	Number of larva	Number per acre
Larva per alfalfa plant, 6" deep	5.4	1,035,440 (On basis of six square inches of surface per plant)
Larvae per square foot of earth, 6" deep	25.6	1,115,136

Thus it will be seen that the per plant total for one acre is approximately the same as that taken by the square foot. This figure results because in taking the per plant counts only about 36 square inches of surface per plant was considered or about one-fourth the area used in the per square foot count.

If eggs laid in September and October are taken in and kept under room temperature they hatch in the normal time.

Likewise eggs which are laid in late June or July hatch normally. However, no larvae have ever been observed to survive under the Kansas fall and winter conditions. Nor has the writer ever found the larvae maturing under field conditions in July or August. They undoubtedly succumb to the hot dry weather during the summer.

Plates II, III, IV, V, and VI show clearly the method of feeding and the migration of the larvae in the soil after they have passed the second molt. The cages from which these pictures came were of glass as described under methods. Young alfalfa roots were used. The plants were set next to the glass in order that the feeding might be noted in detail. Plates II and III are of the same cage.

In Plate II a little space was left between the side of the side of the glass cage and the soil. At the bottom of the picture may be seen burrows made by the larvae in which the soil was pushed up against the glass. This shows that the larvae preferred the darkness and sought it by burrowing rather than by crawling in the space between the soil and the glass.

In Plate II several places of feeding are of interest. On the left in about the center the largest root has been cut off completely for a distance. Small white, enlongated masses appear at the place of feeding. Part of this

material is larval defecations and part is small pieces chewed off the root but not swallowed. It may also be noted in this picture how the larva followed the large alfalfa root, feeding in several places as it went. The more nearly mature the larvae are after finding the large roots the less they move from one feeding spot. Considerable feeding is done at this time and it is then that a great amount of damage is done to such plants as white clover. In a number of cases the writer has found clover plants cut off just below the surface of the ground. This destruction of the plant may occur on young alfalfa or any such legume in which the main root is three-eighths inches in diameter or less. In Plate II it will be noted that practically the entire root system of the plant on the right has been consumed by the larvae. The longest plant in the cage shows that about one-half of the tap root has been eaten.

Plate III is an enlargement of the area of greatest feeding in the cage shown in Plate II, and shows at least four places where the alfalfa root has been completely severed. It will be noted that the entire distil end of the large alfalfa plant has been consumed. Other feeding has been done on this root as seen in Plate II.

Plate IV shows an enlarged view of what happens to clover or young alfalfa roots after the larvae are old enough to seek the larger roots. The center root has been eaten for a considerable distance. The larva can be seen about the center of the eaten area. Defecations may be seen as white masses mixed with the darker soil particles of the area. In the lower left hand corner of the picture is a large root nodule.

In Plate V may be seen seven larvae some of which have pupal cells under construction. The larvae are not distinct on account of the fact that they were alive and moving when the light was turned on them as the picture was taken. The extent of movement of these larvae through the soil may be seen in this plate. As will be noted this area is enlarged about five times.

Plate VI shows clearly the damage by Sitona larvae to three year old alfalfa roots. The plants in this picture have been reduced approximately one-third in size and show the appearance of the roots just after the larvae have pupated. In the literature the greatest depth of injury to the roots has been recorded as five inches. On plant 1 a feeding injury has been made about eight inches below the surface and shows at the corner of the number in the lower left hand corner.

Plants 1 and 3 show the typical long grooved type of feeding. Plant 2 shows the circular gouges as well as many short grooves that girdle the roots.

On all three of these roots may be seen the extensive injury near the crown of the plants. This injury is in many cases more serious than shown here but is not due directly or entirely to the larval feeding. The larvae feed extensively at this point and provide the most favorable source of infection possible on the root. Through these openings diseases enter and often the plant succumbs to alfalfa wilt or other diseases. In some cases the larvae burrow into the roots for a short distance. This sort of feeding causes confusion between this species and Hylastinus obscurus (Marsh.). The latter species belongs to the family Ipidae, however. The clover root curculio larvae seldom tunnel into the roots more than one-half inch. Infection of roots by diseases is most noticeable following wet backward springs. Even though it is definitely known that the injury caused by the larvae of the clover sitones is the cause of a great many more alfalfa root diseases than would otherwise be the case, there is a great deal of work to be done on the problem yet before a thorough understanding of the interrelation between the diseases and the larvae will be reached. At present, water injury, winter

injury, and diseases entering through root injury are much confused.

The spring of 1928 and that of 1929 were both more rainy than usual and the question was raised as to the ability of the larvae to withstand so much water. Several larvae were collected and put into a cup of tap water. They floated unless pushed below the surface. Those which were made to sink to the bottom did not drown for thirty-four hours. These larvae were in the third instar.

Pupa. The pupal cell is earthen, oval in shape, and is usually found within three inches of the surface. The larva shapes the cell by the use of the mandibles. The turning of the body also aids in the construction. As the larva pushes its mandibles and head capsule against the cell a liquid from the mouth is also added to the soil. This prevents the cell from crumbling and aids in keeping out the water. Two or three days are necessary for the construction of such a pupal cell.

In Plate III may be seen a pupal cell which the adult has vacated. Plate II shows the same pupal cell and also the path traversed by the adult in reaching the surface at the time of emergence. These cells are easy to detect in both Plates II and III. Pupation takes place in most cases very close to the root upon which feeding was done.

The creamy white pupa of the clover sitones is very delicate but quite active. The wings are translucent and folded one above the other at the sides between the second and third pair of legs, partially covering the third pair. Neither the legs nor the wings are compact against the body. The head supports several large bristles or papillae and is prolonged into a conspicuous beak. The body is 4 to 5 mm. long, and the head is from 1.48 to 1.62 mm. wide. The females are noticeably larger than the males. The abdomen especially on the dorsum stands out ridged.

The pupal period varies broadly from eight to sixteen days in length. In 1928 most of the adults emerged after eight days. In 1929 it took from 10 to 14 days. The females develop a little more slowly than the males and require two days longer.

Near the end of the pupal period the eyes turn a reddish brown, the next day the beak darkens somewhat and the following day the wings have expanded and are in their natural adult position. The entire body has begun to turn brown. Another day is spent in the cell after which the new adult begins to burrow toward the surface.

The great majority of the sitones larvae pupate about the same time althoggh a few pupate early and a few stragglers may be found even in the middle of July. During

1928 and 1929 holes were dug in the alfalfa field and the numbers of larvae and pupae found were counted. This would give a fair idea of the time of pupation of most of the larvae. Eight counts were made between the dates of 5-31-28 and 7-2-28. From June 7 to June 25 the greatest numbers of pupae were found. This condition was true for both years. The normal pupal period under field conditions in spring was found to be eight days. Adults reared at room temperatures during December required from 17 to 19 days. Those reared in glass cages at room temperatures during June 1929 required from 10 to 17 days.

Adult. The adult clover sitones is a medium brown to black hard bodied beetle measuring from 3.3 to 4.7 mm. in length. The elytra are rather broad and short and striated with large punctures and conspicuous raised setae. The scales are much variegated in color in the same specimen and occur in dark and light groups. On the thorax are found two broad subdorsal bands and a narrow interrupted dorsal line composed of ochraceous or whitish scales. For further description see Jackson (16) and (17). The adults feign death when disturbed, but not to the degree as does Hypera punctata (Fab.). They seem to be weak fliers and Jackson (16) has described the occurrence of alary dimorphism in this species.

A few days after emergence of the adult it begins to feed. The time recorded for the emergence is from June 15 to July 5 although most of the adults have appeared by June 25. Feeding is resumed till cold weather without being broken by a period of oestivation.

In the fall the adults copulate and eggs are laid on warm days during September and October. Two adults observed by the writer in copula at 9:15 a.m. continued so at intermittent intervals till 12 m. Eggs may be laid twelve hours after copulation.

With the advent of cold weather the adults hibernate beneath debris in the alfalfa field. The adults have been taken throughout the winter in the fields. Overwintering cages used during the winter of 1928 and 1929 failed successfully to hibernate any adults although debris was heavy in the cages. Adults were not hard to find in the field, however. When too little shelter is to be had the winter mortality is very high (12). In notes on file is recorded a method of collecting adults. A large rug is placed on a white clover or blue grass lawn and left during the evening. If examined after dark often hundreds of these curculios may be taken from the under side of it.

Natural and Artificial Control

The natural enemies of the clover sitones are rather limited. Howard (12) gives the Upland plover, killdeer, ruffed grouse, broad winged hawk, flicker, night hawk, chimney swift, wood pewee, crow, blackbird, meadow lark, Lincoln finch, song sparrow, chipping sparrow, and the white throated sparrow as bird enemies. Jackson (17) records three Braconids which attack the adult beetles, Perilitus rutilus Nees, Perilitus aethiops Nees and Pygostolus falcatus Nees. Gregarines belonging to the genus Gregarina also attack the adults. According to Jackson the fungus Botrytis bassiana (Balsomo) appears to be the most serious natural enemy of this species and attacks both adults and larvae.

During the past season's work the author observed a disease of the larvae in the field. At one time about every sixth larva taken by diggings was killed by this disease. The larvae became distended, light brown in color and later dried up. Diseased specimens were sent to Dr. G. F. White for identification and the return report gave nematodes of the genus Diplogaster as the cause of death.

Howard (12) found that a fungous disease Entomophthorae attacked the larvae. The success of artificial

control up to this time has been questionable. Blatchley (1) recommends short rotations, Parks (22) and Webster (30) contend that discing or harrowing immediately after the alfalfa crop is cut greatly reduces the number present the following year, but may injure the crop. Gossard (10) found that fall plowing had no effect. Webster (30) tried burning in the fall but with no success. He also found that the adults ate too little leaf tissue to be poisoned. The most promising control is harrowing the field soon after the alfalfa is cut and just at the time of pupation. The damage done to the alfalfa stand would, however, probably overshadow the gain in insects killed. Short rotations seem to be helpful.

HYPERA PUNCTATA (FAB.)

Introduction

In this paper Hypera punctata (Fab.) has been considered the second most important curculeo of alfalfa for several reasons. In the first place outbreaks in Kansas as elsewhere occur sporadically rather than consistently. Second, outbreaks are usually very local. Third, alfalfa eaten to the ground by this insect generally recovers reasonably well. Fourth, in most cases the disease caused by the organism Empusa spaerosperma Fres. decreases the

numbers of this insect to such an extent that outbreaks while common are not frequent. All the stages of the clover leaf weevil are above ground and as a result more conspicuous than the clover sitones. Fifth, the plant parts injured by the feeding of the clover leaf weevil are not such frequent sources of infection of alfalfa diseases as is the case with the clover sitones. Notwithstanding these facts the losses incurred to growers of alfalfa in Kansas are often large.

Losses to the alfalfa growers may occur in several ways. A severe outbreak shortens the life of the stand, decreases hay production for the current year, breaks into and changes the normal plan of rotation, and it may cause additional cash outlay by necessitating the reseeding of the field. If reseeding is necessary, valuable time may be lost in plowing the old and preparing the new seed bed, also nearly a year is wasted before the first crop can be produced. From the time a serious outbreak of this insect occurs until the field is reseeded, whether it is one year or longer, a compounding annual reduction in yield occurs.

An extensive review of the literature on this insect indicates that the greatest damage has been done to clover. For this reason most of the observations and experiments have been carried on with clover as host plant.

Distribution and Host

Studies and observations of the clover leaf weevil were made as early as 1762. According to Titus (28), "It is common all over Europe and northern Asia and in China. Asia Minor and the north coast of Africa appear to be rarely inhabited by this species." A collaboration of the work of several writers gives the area of its distribution in the United States as follows: all states north and east of Tennessee, Mississippi, Texas and Colorado. Damage has been reported from Idaho, Washington, Oregon, California, Utah, and Wyoming. The insect was first collected in Yates County New York in 1881, having crossed from Canada where it was noted as early as 1853 (11). The insect is rather omniverous in its feeding habits especially is this true in the adult stage. It has been found feeding on Jerusalem artichoke, corn, timothy, burrdock, soybeans, golden rod (11), potatoes, wheat, and cabbage (28).

Serious outbreaks of this insect are common to clover fields and occurs though somewhat less often on alfalfa. According to Jaques (18) the damage is most general in the northern states and Canada with New York showing the greatest losses. Although outbreaks are local a constant loss occurs each year within the range of distribution of this

insect. For this reason the aggregate toll is undoubtedly greater than is realized. In most cases the larvae of the third and fourth instars are responsible for the most serious damage though the adults may occassionally cause trouble.

The amount of food consumed by this insect in the different stages has been shown in an admirable paper by Tower and Fenton (29). These authors find that each adult beetle eats on the average of 4.76 square inches of leaf tissue during this stage. In most cases the feeding is done only a little at a time. This does not include the epidermis taken from the stems at the time of oviposition when the feeding habits of the female are altered somewhat. The larva eats 3.09 square inches of which 2.48 square inches are consumed during ten days of the fourth instar. Feeding by the adult is most extensive during two periods; the first immediately after emergence from the pupa, and the second just after emergence from oestivation or during the mating and egg laying period.

Life History

The life history as given by different workers is as follows:

	Egg stage	1st instar	2nd instar	3rd instar	4th instar	Pupa
Gossard (10)	21 days					14-21 days
Hudson and Wood (14)	14-42 days	17 days	21 days	13.1 days	17 days	5-13 days
Titus (28)	35-40 days	9 days	10-12 days	15-16 days	12-15 days	10-20 days
Herrick and Hadley (11)	12-50 days	9-14 days	7-15 days	8-14 days	10-17 days	6-11 days

Egg. The egg when freshly laid is an oval, shining, transluscent, light yellow. The shell is quite pliable, elastic, and very tough. These properties enable the adult to push the egg into small irregular openings. Within 24 hours after being laid the egg begins to change color and finally becomes a dull dark greenish grey. It is about one millimeter in length and from .55 to .65 millimeters in width. The length of the egg stage varies greatly due to varying weather conditions as well as to the time of oviposition. In Kansas the eggs may overwinter before hatching. They have been found to hatch in 11 days if laid during the last few days of September.

Herrick and Hadley (11) working in New York found that on mild winter days the adults come out and lay fertile eggs in which case there are two generations per year. They also

suggest that farther south this probably occurs more often. Two seasons' work at the Kansas State Agricultural College fail to show this to be the case. When the adults go into hibernation oviposition ceases. Eggs are laid in the fall in Kansas as early as September 20. Oviposition continues as long as the temperature is above 50 degrees. These eggs generally hatch and the larvae reach the second or third instar before cold weather. Eggs may also be laid too late in the fall to hatch before spring. Oviposition has been observed as late as December 11. Since weather conditions determine how late eggs will continue to hatch the date of fall hatching varies from year to year.

At this station as high as 81 eggs were laid between October 2 and November 11. Counts showed that only 33 per cent of the larvae from eggs laid in the fall of 1928 hatched before winter. The other 67 per cent hatched the following spring.

Hudson and Wood (13) working in Ontario, Canada, report one caged female which layed 667 eggs during a period of 76 days of which laying was actually done on 46 days. Of 4500 eggs these same workers found that 55 per cent were laid in the petiole of the leaf and 27 per cent in masses outside the main stem. The remainder were laid on the soil and sides of the cages. These observations were for clover.

Herrick and Hadley (11) found the most favorable place for oviposition is in wheat or old alfalfa stubble. The length of the egg laying period was found in some cases to be from August 25 to November 20 with greatest oviposition during September. Eggs laid later than the last weeks of October hatched the following spring. Those which overwintered with the embryo fairly well developed always had a high mortality (11). Crosby and Leonard (6) observed oviposition taking place only at night. Hudson and Wood (15) found that temperature stimulates and retards oviposition more than darkness. Egg laying as well as feeding ceases between 50 and 45 degrees.

Oviposition as noted by Hudson and Wood took place about as follows: The female becomes restless. She walks up and down the stem apparently seeking the proper place. She never selects a tender young stem but more often a stem which is rather old or even dry. A small hole is then rasped into the pith of the stem. This the female does with head downward. No material is eaten from the egg puncture but this is not the case with a feeding puncture. The female then reverses her position inserts her ovipositer and begins laying eggs. She places the eggs with her ovipositer and when she is through she leaves the spot without even inspecting the work. Frequently two or three eggs are laid

just outside the egg puncture and often cannot be pushed in although the eggs are battered considerably with the genital plates. While the eggs are being probed apparently to insure their sticking to the stem they are covered with a copious flow of viscous liquid from the ovipositer. In one case 24 eggs were laid in 25 minutes. If a puncture is made but no eggs laid the opening is sealed down tight. Crosby and Leonard (6) state that the eggs rarely overwinter but hatch in the fall. Tower and Fenton (29) found 25 eggs which had been inserted through one puncture in the stem. They were pushed 3.5 mm. above the opening and 6 mm. below.

Larva. The larvae hatch by cutting an irregular slit in one end of the egg through which they crawl. A newly hatched larva is nearly white except for a light brown head capsule. The ocelli are prominent, but small. The head capsule is about .35 millimeters wide and the body length ranges close to 1.75 mm. The larvae taper anteriorly and posteriorly, and assume a curved position. Upon feeding most of the larvae soon turn light green, although a certain percentage remain nearly white until pupation.

The very minute first instar larva crawls up on some green part of the plant after remaining for a short time near where it hatched. Being legless another method of locomotion must be used. The larva first grasps a hair-

like projection on the alfalfa stem with its mandibles. It hangs on this way by contracting the abdomen, then it extends the head and grasps with the mandibles. It contracts its body somewhat and grasps this time with the ventral folds. Thus it holds on to the stem while it extends the head to grasp again with the mandibles. Seldom does a very small larva climb to the higher points on the stem. A developing terminal bud somewhat lower down seems to be almost the ideal spot. If this be the case the larva forces its way between the tender folded leaves. It feeds by eating small holes in these expanding parts. There is little movement from this place unless it is blown off or otherwise removed mechanically. Many larvae perish soon after hatching if removed from the plants by wind or rain. After the first molt a larva feeds from the margins of the leaves and irregular notches are cut out. During bright days the larva may be found snugly coiled with the end of the abdomen overlapping the head and lying at the base or a short distance from the base of the plant. There a covering of dead leaves is sought. At night the larva crawls up the stem again to feed. These records are based on observations made by the author at the Kansas Station during the summer of 1928. According to Herrick and Hadley (11) the larvae feed only at night after the first molt. In Kansas this is

not necessarily the case. During the spring of 1929 the weather was cloudy much of the time. On such cloudy days larvae in all stages could be found feeding any time during the day.

The clover leaf weevil undergoes four molts and after each the superficial characters change somewhat. The body becomes a rather bright green often with a pinkish cast. The head capsule darkens and a mid dorsal white line appears as the larva becomes robust. During the last instar the larval head capsule measures from 1.15 to 1.25 mm. in width and the body length from 10 to 15 mm.

As will be seen from the summary of the life history of Hypera punctata (Fab.) as given by different authors the different instars vary a great deal with different localities. It is commonly understood that the larvae overwinter in debris and in hollow stubble. H. E. Jaques (18) observed thirty or more larvae feeding at the base of one clover plant. A furrow plowed through a sixty-five acre field in Alberta, Canada, yielded one hundred five larvae per foot one day later. At this station as high as eight larvae and several cocoons were taken at the base of one plant.

The following table shows the number of instars and the width of the head capsule for each instar.

	1st instar	2nd instar	3rd instar	4th instar
Maximum	.378 mm.	.65 mm.	.9 mm.	1.15 mm.
Average	.35 mm.	.10 mm.	.85 mm.	1.20 mm.
Minimum	.251 mm.	.55 mm.	.70 mm.	1.25 mm.
Days in Fall at Room Temperature	7-15	8-11	6-11	6-10

The larvae will mature under room temperatures in from 27 to 47 days. The larval period would probably never be this short under field conditions but these figures give an indication of the possibilities if very mild weather prevailed. Rearings have been made in which the length of time elapsing from the egg to the adult was only 53 days. From such a short period under insectary conditions to overwintering larvae which take seven and one-half months to develop we have every variation. The larvae sometimes pupate as early as May 1 in Kansas and the latest date recorded for pupation was August 12. Pupation in the greatest numbers usually occurs about May 27 to June 4.

As shown by Tower and Fenton (29) the fourth instar larva feeds extensively. Since this fourth instar larva appears about the time the second cutting of alfalfa is made in Kansas it is apparent that serious damage may result before the new growth starts, if the numbers of larvae are

large.

Pupa. From two to five days are spent as a propupa at which time the pupal cell is spun. According to Titus (28) the mature larva buries itself just below the surface of the soil or beneath debris. At this Station cocoons have even been found in the pith of old corn stalks. A cell is smoothed with the head. The spinning is done with the mouth and the first threads are placed as a round network on the surface where the larva lies. Then the larva lies on its back and reaches over its abdomen spinning the thread slowly upward over itself. At times a thread is carried over to the opposite side thus forming a frame work. More often the threads are laid down on each side and gradually built up. The larva often puts its mouth through the coarse network and fastens a thread to the outside. The meshes are reduced in size by spinning other threads in both directions over the first rows. Every half minute the larva reaches back to its anus and apparently gets a new supply of silk. At this operation the larva partakes the character of both sucking and nibbling. At times it appears that silk is not being formed as rapidly as it is used. In this case the larvae kneads the last few abdominal segments with its head. Observations of 700 pupae at the Kansas Station in the field cages gave 6 days as the shortest time and 22 days as the longest recorded pupal stage. These ob-

servations are the result of at least three years' work. The average length of the pupal period was found to be 15.1 days.

Adult. The adult remains in the cocoon several days after shedding the pupal skin then emerges by chewing one end from the cocoon. After emergence from one to four weeks are spent in feeding, the activity being confined to dark days and nights. Several workers have described a period of oestivation which normally occurs at the end of the above mentioned feeding period. Cage experiments in 1928 confirmed these reports. Additional work was done to determine the actual length of time that adults would live in mid-summer without food. In order to determine this cages were placed over alfalfa and several weevils were placed in each. After a time the alfalfa in the cages was cut and the ground kept bare of green plants. At the end of nearly three months (July 5 to October 3) about 65 per cent of the adults were alive. Activity was slight throughout this period. Then the weevils were transferred to green alfalfa on which they began feeding with apparently no ill effects. They started mating and laying eggs after about a week.

The clover leaf weevil distributes itself by flight. Flint (7) says they are strong fliers. Ross* working in

*53rd Ann. Rept. Ent. Soc. of Ontario, 1925.

Canada states that a shower of these adults occurred at Windsor in the late summer and fell on roofs and lawns. When they alighted most of them were dead and they could be gathered up in great numbers for several weeks. Estimates of the numbers were in the millions. The length of the adult life as given by other writers varies a great deal. Overwintering cages were put in the alfalfa field during the winter of 1928 and 1929. Four per cent of the adults successfully overwintered. Of these one adult was still alive and active at the writing of this paper.

Control

Artificial. This alfalfa pest is often controlled by natural agencies. Artificially it has been prevented from doing serious damage by the use of arsenate of lead. According to Larrimer (19) two pounds of lead arsenate to 50 gallons of water to which was added one pound of soap killed 95 per cent of the larvae. Jaques (18) states that 90 per cent of the larvae were killed with one application of this spray. In a few cases as shown by Westgate and Hillman (31) the feeding on clover done by this weevil is a benefit to the farmer on account of the fact that feeding delays the development of the crop till the time for clover midge injury is past. Gossard (9) tried rolling the field with a

1100 pound roller to control the larvae and it was found upon examination that not one larva could be seen which had been injured.

Natural. The most effective natural control is by the fungous disease Empusa spaerosperma Fres. This disease is explained in detail by Titus (28) and so will be but briefly mentioned here. It spreads by spores from larva to larva, killing them a few days after the infection has entered. Before dying the diseased larvae crawl high up on the alfalfa plant and curl tightly around the leaves or stems.

A species of small Chalcids was reared from the pupae of this insect during the summer of 1928. The adult Chalcids oviposit in the larvae which pupate but never emerge. The Chalcids then emerge from the cocoons. The name of this parasite is unknown to the writer since the determination has not been received to date.

Other insect enemies are Cicendcla repanda Dej., Collops quadrimaculatus (Fab.), and some tachinids. According to other workers the bird enemies are turkeys, chickens, grackles, Savannah and Vesper sparrows and others.

EPICAERUS IMBRICATUS SAY

Introduction

Epicaerus imbricatus Say., commonly known as the imbricated snout beetle is the third and last Curculionidae known to be injurious to alfalfa in Kansas. Seldom is this insect injurious as an adult. Larvae over three weeks old are unknown to literature. Relatively few entomologists have even seen the eggs although they are not especially difficult to find.

The imbricated snout beetle is a potential pest and has been known to cause damage to crops although no serious occurrence of this kind has been recorded for alfalfa. The adults are one of the conspicuous insects taken in the alfalfa field in late spring and summer.

Distribution and Host

The first mention of this insect in the United States was made in 1863. It was first described in the Journal of the Academy of Science of Philadelphia as Liparius imbricatus. The imbricated snout beetle occurs east of the Rocky mountains except in the more northern states according to Chittenden (3).

Although it is commonly known that the adults are omniverous in their feeding habits but little is known of the habits of the larvae. The adults according to Sandburn (25) are common on beans, peas, radishes, cabbage, cucumbers, watermelons, cantaloupes, squashes, corn, potatoes, and peaches. Chittenden (3) has recorded them as destructive to strawberries in Arkansas. Osborn and Mally (21) report damage by adults to alfalfa, apples, cherries, gooseberries, onions, beets, plums and pears.

Definite knowledge of larval host plants is scarce. The author has successfully reared the larvae through two instars on white clover and alfalfa.

Natural Habitat

Many larvae of varying stages of development have been collected from holes dug in a blue grass pasture. Also many larvae have been found by digging in prairie grass pastures in which buckbrush, cocoa, or nut grass (a sedge) and a legume (Psoralea) are found growing. Two situations in the near vicinity of Manhattan, Kansas, were found to be particularly important in the study of this insect. The first is the upland prairie on which is found the regular eastern Kansas prairie sod. Figure 1 gives a graph of this first situation. The results recorded in this figure

are based on fifty larvae of Epicaerus imbricatus Say. collected by the digging of holes two feet by three feet and as deep as insect life could be found. In these holes the larvae were collected at varying depths. At least one hole was dug each month in this locality. Figure 1 gives the variation in depths at which larvae were taken. The solid line represents the average depth, the upper line the minimum, and the lower line maximum depths at which larvae were taken in each hole for each month.

The second situation shown in figure 2 is of the lowland situation. This locality is in a pure blue grass sod and is used for pasture land. This figure gives the same information for the second locality as figure 1 does for the first. The results in figure 2 are based on fifty-eight larvae and a newly emerged adult collected by the digging of thirteen holes. The average maximum and minimum depth of the larvae for each month are plotted.

Figure 3 gives the monthly moisture percentages at 6, 12, 18, and 24 inches for the upland prairie situation, and corresponds to the results given in figure 1. Figure 4 gives the monthly moisture percentages for the lowland bluegrass situation and corresponds to the results given in figure 2. Samples for these moisture determinations were taken at six-inch intervals when the holes were dug.

FIG. 1

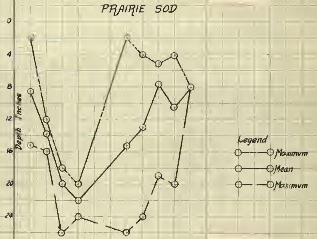

PRAIRIE SOD
0
4
8
12
16
20
24
Depth Inches
Legend
Maximum
Mean
Maximum

FIG. 2

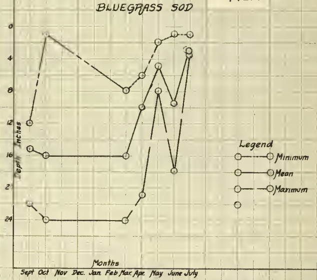

BLUEGRASS SOD
0
4
8
12
16
21
24
Depth Inches
Legend
Minimum
Mean
Maximum
Months
Sept Oct Nov Dec. Jan. Feb Mar. Apr. May June July

FIG. 3

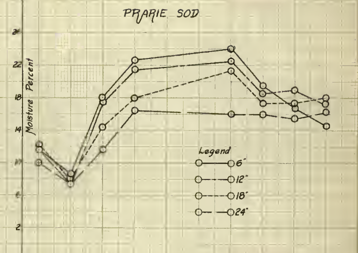
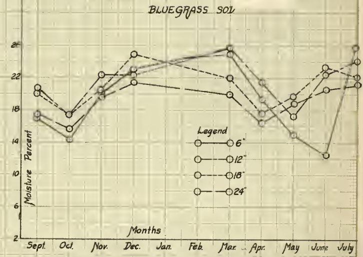

PRARIE SOD
Moisture Percent
2
6
10
14
18
22
26
Legend
6"
12"
18"
24"

FIG. 4


BLUEGRASS SOD
Moisture Percent
2
6
10
14
18
22
26
Legend
6"
12"
18"
24"
Months
Sept.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
July

Life History

A satisfactory knowledge of the life history of *Epicaerus imbricatus* Say. at the present time is unobtainable. Much damage by the adults has been recorded for a wide variety of plants.

In 1928 the author was unable to learn anything new about this species. During the spring and summer of 1929, however, several facts, bearing toward a knowledge of the life history of this insect were obtained.

Egg. The eggs of the imbricated snout beetle are subcylindrical and white at first, later becoming a very light yellow. Often the color of orange juice, both ends being somewhat lighter under a microscope on irregular reticulation is observed as a raised network over the surface. Thirty-seven eggs were measured and the average length found to be 1.404 mm. and the average width .54 mm. wide at the broad end and .405 mm. at the narrow end. The shell is very thin and tough. The adult beetles are found mating from late May till about July 15 or later. Eggs are laid a few days after mating. In alfalfa two leaves are glued together, or many times one margin of a leaf is glued to the other. After sticking the leaf together in this manner the ovipositer is inserted and from 1 to 18 eggs laid. The eggs are sometimes laid in rows but this is not necessarily the

case. They are seldom laid on on top of the other however. In the field the leaves containing the eggs stay green. The writer has often put the leaves containing the eggs in salve boxes for hatching. The salve boxes contained moist blotter. In many cases before the eggs hatched the leaves had shriveled and were rotting and badly molded. In every case practically 100 per cent hatch was obtained. One female under the writer's observation laid 123 eggs in fourteen days. Eggs laid in June hatched in from 8 to 12 days, most of these hatching in nine days. The larval body shows plainly through the shell at least 24 hours before hatching. When attempting to break the shell the larva moves the head backward and forward as far as possible often bending it down against the abdomen, opening and closing the mandibles at the same time. Apparently a secretion from the mouth weakens the shell by partially dissolving it. Finally a split in the broad end of the egg appears about where the mandibles rest against the shell when the larva is in the normal position. After the shell splits, with much wriggling and chewing the larva crawls through the opening. The shell collapses as the larva leaves the egg.

Larva. Unlike sitones these larvae upon hatching drop from the leaves to the ground, seek shelter from the hot sun by crawling beneath something, and immediately burrow

into the soil. The manner of digging is very much like that of a clover sitones larva but much more rapid.

The newly hatched larva is white with a light brown head. Behind the head is a broad rectangular prothorasic shield. This is white, glistening, and slightly more narrow in the center than at either margin. The abdomen is broadest just posterior to this shield and tapers toward the anal end. The larvae have no legs, but a pair of anal prolegs occur on the caudal end. The ventral side is rather flat, with dorsal and lateral surfaces rounding. On the latero-ventral surface is a rather prominent ridge which runs from the head to the anal end. This ridge is divided by a broad shallow wrinkle which runs the full length of the abdomen. At hatching one stiff bristle protrudes where the legs normally would. After the second molt three are present at each place.

Before the first molt the larvae chew at anything which comes within reach of the mandibles even though it be decaying organic matter or growing roots. The writer tried in vain to observe definitely whether or not dead material was actually eaten. Before the first molt the larvae were not observed to follow a root to obtain food but instead they seem to depend upon any food that they come across. After molting however they become more transluscent, the

contents of the crop shows through the body wall dorsally and they follow the roots by digging alongside them and consume them entirely as they go. Instead of depending on packing the dirt tightly behind them with the anal end the larvae turn around often and push at it with the head capsule and mandibles.

In the last instars the head capsule becomes very hard, a dirty white in color, and shiny. The surface is coarse in appearance and irregularly punctate. At each molt the larva prepares a roomy earthen cell and rests two or three days before shedding the exuvae.

Since time has not permitted the rearing of this insect through the entire larval period it is impossible to state definitely the number of instars during the life of the larva. The table below gives the head capsule measurements of the larvae up to the writing of this paper.

Number of eggs	Date Laid	Date Hatched	Width of head capsule when hatched	6-23-29	7-9-29
8	6-5-29	6-17-29	.27 mm.	.292 mm.	.505 mm.

This data shows at least two molts with a possibility of one between 6-23-29 and 7-9-29. Before this time the longest period the larvae could be kept alive was 3 weeks. Up to the third molt no noticeable difference in width of

head capsules among different individuals was recorded.

Larvae collected in the field were all fairly large as will be seen from the head capsule measurements given below. Since the number of instars cannot be determined with the data at hand all the different head measurements noted are listed below:

1. 0.918	5. 1.997
2. 1.566	6. 1.998
3. 1.728	7. 2.214
4. 1.944	8. 2.376

Number 7, the largest larva collected, was measured 6-28-29 and again 7-7-29. The width of head capsule at the latter date was the same as number 8. A molt had taken place between these dates.

From the data collected and the slow rate of growth of these larvae, it would seem that those which hatch in June probably mature in late fall, go below the frost line, pupate there, and emerge the following spring. Larvae with head capsule measurements the size of number 7 and 8 however were collected from holes in June which indicates an irregularity in the maturing of the larvae. Not only large larvae were found in holes dug in June but also larvae measuring .918 across the head as well as several different sizes between these two extremes.

If the egg laying period extends from May 15 to August 1, it is reasonable to expect this irregularity in

the maturity of the larvae. No attempt was made to correlate the depth of the larvae in winter with the size at such depths but undoubtedly this might shed much light on the subject since there is such a wide range of depths at which the larvae may be found.

Pupa. Pupation to some extent occurs in late fall or winter because one newly emerged adult was found at a depth of twelve inches on March 7, 1929. This adult was in an earthen pupal cell and still retained its mandibular appendages and so it had not attempted emergence. The pupa of this species if seen has never been recognized.

Adult. Since no adults have ever been reared under observation little can be said concerning the date of emergence. They first appear about the middle of May. This would indicate spring emergence.

How long the adults live is not known. Chittenden (3) records an adult which laid 540 eggs between the period of May 17 and June 6. He states that the adult was active 57 days and that after death twelve more unlaid eggs were found in the female.

OTHER SPECIES OF CURCULIONIDAE FOUND IN ALFALFA

The accompanying list of insects are those which are taken in alfalfa yet which are known or supposed to be

feeding on some other plant in the field besides alfalfa. None of these insects have been found definitely responsible for injury to alfalfa although many of them have been observed closely during the period this problem was in progress.

1. Lixus musculus Say.
2. Rhodobaenus tredecempunctata Tus.
3. Sitones linellus Gyll.
4. Sitones apacheana Csy.
5. Apion (species not known)
6. Baris transversa (Say.)
7. Rhyssematus palmicollis Say.
8. Onychobaris Spt.
9. Centrinus picumnis Hpst.
10. Centrinopus helvinus Csy.
11. Desmoris constrictus Say.
12. Dorytomis indifferens Csy.
13. Rhinoncus pyrrhopus Boh.
14. Geraeus penicellus Hbst.
15. Geraeus picumnus Hbst.
16. Conotrachelus seniculus Boh.
17. Ceutorhynchus rapae Gyll.
18. Ceurorhynchus sulcipennis Lec.

19. Ceutorhynchus neglectus Blach.

20. Brachytarsus sticticus Boh.

The last species, Brachytarsus sticticus Boh., is not a curculonoid but is an Anthribid. It is very common in alfalfa the year around and is often mistaken for a true weevil.

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SUMMARY

1. There are at present approximately 30 species of the family Curculionidae which may be collected on alfalfa in Kansas.

2. Kansas alfalfa growers are concerned with four species of curculios, Sitona hispidulus (Fab.), Hypera punctata (Fab.), Epicaerus imbricatus Say. and Phytonomus posticus (Gyll.)

3. Phytonomus posticus (Gyll.) has not gained a foothold in Kansas but it may be found in the state any time.

4. The entire life history has been observed for Sitona hispidulus (Fab.) and Hypera punctata (Fab.).

5. The breeding grounds, subterranean habits, food plants, seasonal occurrence, and oviposition of E. imbricatus Say. have been studied.

6. The border vegetation around an alfalfa field influences to a certain extent the species of curculios found in the alfalfafield.

7. Certain species are known to be breeding and feeding on plants other than alfalfa in or around the field.

8. The interrelation of Sitona hispidulus (Fab.) and several alfalfa diseases appearing simultaneously with root injury by this insect is a problem well worthy of considerable study.

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PLATE II

PLATE III

PLATE V

PLATE VI